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CONTRIBUTIONS FROM THE HARVARD MINERALOGICAL MUSEUM. — XIV.

CRYSTALLOGRAPHIC NOTES ON MINERALS FROM CHESTER, MASS.

BY CHARLES PALACHE AND H. O. WOOD.

WITH A PLATE.

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CRYSTALLOGRAPHIC NOTES ON MINERALS FROM CHESTER, MASS.

By Charles Palache and H. O. Wood.

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The minerals of Chester, Mass., have long been the subject of investigations by many mineralogists, especially from the chemical and genetic standpoints. All such studies are cited, and their substance, together with very much more that is original, is fully presented in Emerson's well-known works.[1] The following notes, chiefly crystallographic, are presented because this aspect of the Chester minerals has been almost wholly overlooked in what has been hitherto published. The material studied was collected by the authors during the years 1902, '03, and '04, at the end of the last working period of the emery mine. The observations on diaspore were made by Mr. Wood; the remainder of those presented in the paper, by the senior author.

Diaspore. Diaspore crystals from Chester were first described by Dana,[2] whose brief paper remains the sole crystallographic study of any Chester mineral. Since his description appeared the mineral has been found in several new phases which seem to deserve added record.

Diaspore occurs in three fairly distinct habits:

Type a, long and slender, acicular or bladed crystals.

Type b, flat, disc-like crystals, tabular parallel to the brachypinacoid, with narrow prism and pyramid faces and larger, curved brachydomes.

Type c, short, stout crystals having prisms and pyramids about equally developed, sometimes quite without the brachypinacoid, and then prismatic parallel to the *a* axis.

[1] B. K. Emerson, A Mineralogical Lexicon of Franklin, Hampshire, and Hampden Counties, Mass., Bull. U. S. G. S., **126**, 1895. The Geology of Old Hampshire County, Mass., Monograph U. S. G. S., **29**, 1898.

[2] Dana, E. S., Mineralogical Notes: Diaspore from Chester, Mass., Am. J. Sci., **32**, 388 (1886).

There is of course more or less gradation between these types.

Type a. Diaspore of this habit occurs as the filling or inner lining of drusy lenses or veins of corundophyllite in emery. Usually the space is completely filled with bladed diaspore, and when broken open presents an attractive network of long narrow cleavage surfaces of brilliant lustre. Occasionally irregular angular openings are left in which grow the delicate acicular crystals, sometimes quite spanning the cavity, sometimes with one end free and showing terminal planes. They vary in color from amethystine to gray or water-white with brilliant vitreous lustre. Isolated needles were noted with a length of 15 mm. or more, and a diameter of not more than 1 mm., but most of them are shorter and stouter. With them in these cavities are beautiful bipyramidal crystals of pale green amesite, sagenitic rutile, and magnetite crystals, giving a most attractive appearance under a powerful lense.

The following forms are found on crystals of this habit: b (010), a (100), h (210), m (110), k (230), l (120), e (011), p (111), s (212), u (344), x (133), d (455), and g (788). Two of these, d and g, are new forms; all are discussed below. The prism zone is striated in the direction of its length, as is the zone of pyramids between p and e. Figures 1 and 2 illustrate this habit of crystal. To this type belongs also the crystal described by Dana,[3] on which were the forms b, a, h, l, e, p, s, u, and v (122).

Type b. The disc-like diaspores occur in lenticular druses which have remained partly open, and on the walls of open cracks in emery. The backing of these druses is usually the emery itself with admixed chlorite and without the distinct layer of corundophyllite, as described for the first type. In color the crystals are usually light green, yellowish, or amethystine, and are less brilliant in lustre than those of type a. They are tabular parallel to the brachypinacoid, with maximum dimensions across the plate of 8 to 10 mm. and thickness of 1 to 2 mm.; usually, however, they are much smaller and paper thin. They are ordinarily attached by prism faces to the vein wall and stand out at right angles, exposing both upper and lower terminations; the disc-like form of the plates is due to the rounded surface, resulting from the oscillation of pyramids and brachydome as shown in Figures 3 and 4. While the crystals are usually implanted separately, they sometimes are in contact to form a drusy surface not unlike that which prehnite ordinarily presents.

The forms observed on this type are but few: b, h, e, p, and s.

Crystals of this type were at one time found in considerable abun-

[3] Loc. cit.

dance in the mine and were much prized by collectors, the broad surfaces, covered with richly colored amethystine crystals, making showy specimens. Such a specimen now in the Harvard Mineral Cabinet, presented by the Ashland Emery and Corundum Company, measures about 20 cm. square and is covered over most of its area with platy crystals, backed by pale green chloritic emery.

Type c. Crystals of stout prismatic habit characterize the most recent discoveries of diaspore at Chester. The combinations are simple, generally showing only b, h, e, and s, with l, x, and v less frequently developed. The crystals are always implanted upon a prism plane, and the two developed faces of the prism h are prone to show deep vertical striations without, however, losing their brilliant lustre. Occasionally the brachypinacoid is reduced in size or lacking, and the faces of e more or less curved, giving the crystal a curious lense-shaped form. The crystals are glassy and transparent, with rich colors, ranging from rich brown through wine yellow and green to pure amethystine, often mingled in the same crystal.

The largest crystal seen was a square prism 1 cm. long with diameter of 5 mm.; smaller crystals are, however, the rule. They are implanted, singly or in small groups, in cavities in well-crystallized corundophyllite; a second generation of microscopic crystals of the same type is often present in the cavities, dusting the larger diaspores and chlorite crystals with sparkling gem-like points of light. The habit was also found on very brilliant crystals of about 1 mm. size coating cracks of but a few mm. width in solid emery. All veins containing diaspore of this habit seem to have had a final filling of all open spaces by dolomitic calcite, the removal of which with acid revealed these very beautiful and unusual crystallizations of diaspore. The habit is illustrated by Figures 5, 6, and 7.

Crystallography: Fifteen crystals were measured, the results of the observations being presented in the annexed table. Besides the two new forms there given a number of measurements were obtained from pyramid forms which, either because of poor quality of the faces or complex indices indicated, did not seem established with certainty. These are recorded at the end of the table. It is to be noted that in all forms the agreement between calculated values and mean observed angles is less close than could be desired, or, from the appearance of the measured crystals, expected. The variation is, however, quite irregular, and because of this no attempt was made to calculate a new axial ratio for diaspore from the measurements.

Observations on the forms:

b (010). Natural faces of this form occurred on all but two of the

crystals measured. Only three of the observed faces were cleavage planes, one each on three different crystals. Some of these faces were smooth with a few hair-like striations on them, but for the most part the form is striated considerably from oscillatory combination with the

TABLE OF OBSERVED MEASUREMENTS ON DIASPORE.

Letter.	Symbol. G'dt.	Symbol. Miller.	Calculated. φ	Calculated. ρ	Measured. φ	Measured. ρ	Limits. φ	Limits. ρ	No. of Readings.	Quality of Images.
			° ′	° ′	° ′	° ′	° ′ ° ′	° ′ ° ′		
b	0 ∞	010	0 00·	90 00	0 00	90 00	... ...	... ...	24	excellent
a	∞ 0	100	90 00	"	90 00	"	... ...	... ...	2	...
h	2 ∞	210	64 53·	"	64 58·	"	65 25–63 43	... ...	38	very good
m	∞	110	46 51·	"	46 46	"	47 00–46 26	... ...	5	fair
k	∞ ⅔	230	35 25·	"	35 06	"	35 48–34 01	... ...	7	good
l	∞ 2	120	28 05	"	27 59	"	29 15–27 39	... ...	11	fair
e	0 1	011	0 00	31 07·	...	31 06	... ...	31 13–30 50	10	poor
w	1 0	101	90 00	32 48	...	...	... ...	... ...	1?	...
p	1	111	46 51	41 27	47 18	41 04	47 52–46 06	41 29–41 00	9	good
*s	1 ½	212	64 53·	35 26	65 01	35 31	66 00–64 15	35 46–35 24	25	very good
q	1 ⅔	232	35 25·	48 01·	...	...	... ...	... ...	2?	...
x	⅓ 1	133	19 35	32 39·	19 45·	32 40	20 21–18 51	32 49–32 32	8	good
v	½ 1	122	28 05	34 23·	28 22·	34 22·	29 41–26 48	34 49–33 32	7	poor
u	⅔ 1	344	38 40	37 43	38 43	38 09	38 59–37 10	38 49–37 28	3	poor
*d	⅘ 1	455	40 29	38 27	40 52	38 28·	41 50–40 18	38 36–38 15	4	good
*g	⅘ 1	788	43 02	39 34	42 08	39 05·	43 03–41 23	39 35–38 42	4	fair
					UNCERTAIN FORMS.					
	0 ⅘	043	00 00	38 50	2 01	39 02	... ...	... ...	1	fair
	1 ⅝	545	53 08	38 51	54 09	38 59	54 41–53 37	39 14–38 45	2	good
	1/12 1	1·12·12·	5 05	31 13	4 51	31 10	5 29– 4 13	... ...	2	poor
	⅛ 1	1·8·8	7 36	31 20·	7 21	31 26	7 45– 7 01	31 29–31 12	3	fair
	1/6 1	166	10 05	31 31·	9 28	31 24	9 49– 9 06	31 33–31 22	5	fair
	¼ 1	144	14 56	32 01	15 42	32 29	16 59–13 54	33 20–32 06	5	fair
	⅖ 1	499	25 22	33 46	25 24	33 53	... ...	... ...	1	good
	6/11 1	6·11·11	30 12	34 57	30 32	34 53	... ...	... ...	1	fair

prisms. On crystals of the slender prismatic habit its faces are necessarily narrow, broad on the disc-like crystals and medium on the stout habit. It is the dominant form on the Chester diaspore, and perfect cleavage parallel to it is characteristic of the species.

a (100). Only two faces of this form were observed as line-like

faces on crystals of different habits. Were the form not already known, it would not be recognized on the evidence furnished by this suite.

h (210). This form was present on all twelve crystals. It is uniformly good in quality with bright faces very little striated. On the prismatic habit its faces are necessarily very narrow, but they are definite and of excellent quality. It is the dominant prism on Chester diaspore.

m (110). Only five faces of this form were observed, all on crystals of the prismatic habit. Therefore all the faces were very narrow. They varied in quality from very good to very poor, but they were definite and placed close to the calculated position.

k (230). Seven faces of this form were observed, all on crystals of the prismatic habit. The faces are good, unstriated, and well placed.

l (120). Eleven faces of this form were found. It was not confined to any habit, but occurred on all types. It was better developed on the slender prismatic crystals. Sometimes it is badly striated, but again it is found with bright clear faces.

e (011). Ten faces of this dome were seen. It occurs on all types of the Chester crystals. It is seldom quite good, being usually the centre point of a zone of striations. For this reason the readings in azimuth were often slightly displaced. While sometimes dull, it is usually sharp and bright, but sometimes very small.

w (101). One disturbed, doubtful face lay approximately in the position of this form. The form is established or no mention of the observation would be made.

p (111). Nine faces of this form were observed distributed among all three habits. But it finds its best development on the disc-like type where occasionally it is comparatively large and usually sharp and good. The prismatic habit furnished only one of these readings, but in that case the face was quite definite.

* s (212). This form was well developed on ten crystals. It is the dominant pyramid on the Chester diaspore. It is always sharp and sometimes of comparatively good size, but in some of the disc-like crystals its faces are not so large as those of the pyramid p.

q (232). Two faces, both doubtful, one each on two different crystals (one prismatic, the other disc-like), are all the evidence the Chester suite presents of the development of this form.

x (133). Eight faces of good average quality, fairly well placed and confined to the prismatic habit, establish this form on the Chester species. Most of the faces are well defined but small.

v (122). Seven faces of poor quality on three crystals of habits a

and c only moderately well placed would hardly establish this form if it were not already known.

u (344). One face each on three crystals, all of poor quality and only one really definite, are all that could be referred to this form. These fell near the computed position.

*d (455). This form is *new*. All four faces of good quality occur on one crystal of prismatic habit in close agreement with the computed position. The form must be regarded as established. The data follow:

ϕ	ρ	
41° 50′	38° 36′	image of *good* quality
40 52	38 34	" " " "
40 29	38 29	" " " "
40 18	38 15	" " " "

whence,

40 52 38 28· is the *mean* observed position of this form.
40 29 38 27 is the calculated position of this form.

Another crystal of prismatic habit shows one face in approximate agreement with this position, but it is less definite. Because it is so poorly placed that it might equally well be referred to the pyramid *g, another new form described below, it is not included in the tables nor allowed to disturb the mean of the observed values for either d or g.

*g (788). All four faces of this form are found on the same crystal of prismatic habit that showed the form d, the best developed crystal of the suite. It does not agree as well as could be desired with its computed place, but it occurs more definitely on this crystal than some of the established forms occur on any of the crystals examined; therefore it is accepted and presented, but it needs confirmation. The data follow:

ϕ	ρ	
41° 23′	38° 42′	image of *poor* quality
41 25	38 48	" " *good* "
42 42	39 18	" " *good* "
43 03	39 35	" " *fair* "

whence,

42 08 39 05· is the *mean* observed position for this form.
43 02 39 34 is the calculated position of this form.

A face is described under d which might better be referred to this form, except that this is in greater doubt.

Uncertain forms: Except the first two listed, these forms all fall in the same zone with the two last described, between p and e. They are

line faces in a striated zone; measurement of more crystals would probably increase their number, and they are variable in position. They occur on crystals of type a.

Corundum. Veins traversing the emery and containing massive corundum have long been known and are well described by Emerson.[4] One such vein, about 2 cm. thick, was collected in 1904 which showed the following minerals symmetrically developed on the two walls:

1. Ilmenite in thin plates with thin films of chlorite along parting surfaces.

2. Alternating thin layers of margarite and corundophyllite, the latter also projecting into the vein in larger crystals.

3. Rich blue corundum forming the vein centre without open spaces.

Where the corundum-bearing veins are filled at the centre by calcite, crystals are not seldom developed, generally with rounded or rough faces and not measurable. One tiny veinlet in chlorite, however, yielded us exquisite crystals of pure sapphire blue color, transparent and with symmetrical faces, brilliantly lustrous. Although minute, the crystals gave good measurements for the following forms: r (10$\bar{1}$1), s (02$\bar{2}$1), n (22$\bar{4}$3), and h (33$\bar{6}$1). The last named is new and is established by the following angles measured on two crystals with the two-circle goniometer:

Angle between 0001 and 33$\bar{6}$1, crystal	1	83° 09′
		83 02
		83 00
		83 00
		83 03
		83 09
"	2	82 59
		82 52
Average		83 02
Calculated		83 02

This form is recorded by Melczer[5] who observed it on ruby crystals from Burmah as one of a series of weak images given by rounded portions of the crystals. He did not regard the form as established, but only as indicated.

Figure 8 shows the observed combination with little alteration of the actual proportions. The crystal figured was about 1.5 mm. in length.

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[4] Loc. cit., Monograph, **29**, p. 144.

[5] Melczer, G. Zeitschr. für Kryst., 1901, **35**, 570.

Ilmenite. Ilmenite in the form of thin bent plates is one of the familiar minerals in secondary veins at the emery bed at Chester. A phase of the alteration of such a plate to rutile and magnetite was observed in several specimens. The mass of the plate is changed to dull massive rutile, and tiny brilliant octahedral crystals of magnetite are grouped in parallel strings on its surface. Sagenitic rutile in orientated groups on ilmenite plates was also observed.

A second type of ilmenite was discovered in the form of exceedingly brilliant tiny crystals implanted on acicular diaspore in open or calcite-filled cavities. These crystals do not exceed 0.5 mm. in diameter, but attracted attention by their adamantine lustre, which caused them to be mistaken for brookite at first. There is little doubt in the authors' minds that the brookite long since reported from Chester by Shepard and not afterwards observed there was of the same nature as these tiny ilmenite crystals. They are thin, tabular parallel to the base, and are attached by an edge of the table. The base is marked by triangular striations, but, like all the faces, reflects the signal well considering its minute size. Measurement of a number of them revealed the same forms on all: c (0001), a ($11\bar{2}0$), r ($10\bar{1}1$), s ($02\bar{2}1$), n ($22\bar{4}3$), n_1 ($2\bar{4}23$). These forms are shown in Figure 9 in average development; there is considerable variation in the relative size of the different forms on different crystals.

Shepard in his report on the emery mine[6] refers to the occurrence of large crystals of ilmenite (called by him Washingtonite) in white quartz veins within a mile of the northern end of the vein.

Concerning this occurrence Emerson[7] makes the following statement: "There were in the Shepard collection at Amherst, destroyed by fire, great tabular crystals 6 to 8 inches across and 1 inch thick of model-like perfection from the locality mentioned above. They were tabular by the predominence of OP. I cannot find that they were ever described by Professor Shepard."

While in Chester in 1904 the senior author secured from an old local collection a specimen which clearly represents this "lost locality" and which seems worthy of description. It consists of two attached crystals, three and two inches across and half an inch thick, partially embedded in glassy white quartz. The crystals are dull black and more or less covered with scales of rusty mica. They show the forms c, a, r, and n, very sharply developed in about the proportions of the accompanying figure 10. No further information as to the exact location of the vein which yielded the ilmenite crystals was secured.

[6] Reprinted in Monograph, **29**, pp. 122–135.
[7] A Mineralogical Lexicon, p. 107.

Magnetite. Magnetite in crystals more or less perfect is frequently found in veins in the emery. In our specimens we find it most often with dark green corundophyllite crystals and with the sapphire corundum, diaspore and rutile being present occasionally.

The crystals are of two habits: 1, simple octahedrons, often quite large, showing excellent octahedral parting; 2, dodecahedrons with slight modification by octahedral planes, faces of the former always striated parallel to the longer diagonal of its faces, the latter bright. Tiny crystals of the second habit, embedded in amethystine diaspore, have the symmetrical perfection of a model.

Rutile. As stated by Emerson rutile was abundantly formed, following corundophyllite and diaspore, chiefly in the form of acicular and sagenitic growths. These are generally imbedded in calcite. Our material presents abundant illustrations of such growths, the dull to bright red needles showing every variety of sagenitic network and of cyclic and repeated twinning, the groups minute for the most part and very beautiful as examined under high magnification, as with the Zeiss stereoscopic microscope. Much of the sagenitic rutile is apparently in the form of ilmenite plates, which have been altered to rutile and magnetite.

Occasionally crystals of rutile of stouter proportions are revealed in cavities from which calcite has been removed by acid. One such crystal which was measured showed a prism zone deeply striated by oscillatory combination of the forms, a (100) and m (110); the terminal forms comprised e (101), s (111), and g (212), the latter and other uncertain ditetragonal pyramids forming a striated zone between e and s.

Cobaltite. This uncommon mineral was found on a number of specimens collected by us at the emery mine in 1903. It has not been hitherto described from the locality, and this seems indeed to be the first established occurrence of the mineral in the United States.

It occurs in well-formed cubical crystals up to 2 mm. on an edge and in irregular masses surrounded by chalcopyrite. The crystals are brilliant, silver white in color, and show the cube, a (100), octahedron p (111), and pyritohedron e (210), the cube generally dominant. A few crystals, however, show pyritohedral outline, the faces deeply striated, and on this type the octahedron is lacking. Crystals with octahedron dominant were not seen. The free crystals, revealed by removing with acid the enclosing calcite, are implanted on acicular diaspore or on the pale-green amesite variety of chlorite; associated with them are magnetite, ilmenite, rutile, and chalcopyrite, all in distinct crystals. The massive cobaltite surrounded by rims of chalcopyrite occurs in the same veins with the crystals, in parts where it was not so free to develop. The veins in which it occurs are always bordered by comparatively thick

walls of corundophyllite and cut massive emery. The cleavage and general physical appearance of the mineral, together with distinct chemical tests obtained for cobalt, arsenic, and sulphur, permit no doubt that these specimens represent cobaltite. The material at hand is not sufficient in amount for a quantitative analysis.

It is interesting to note in this connection that the analyses of serpentines of the Chester Formation recorded in Emerson's work[8] show in a number of cases the presence of minute amounts of cobalt and nickel; in view of this evident source of the material for the formation of the cobaltite it seems probable that analysis of the cobaltite would reveal a nickel content.

Pyrite. Pyrite is abundant in the chlorite schist containing tourmaline which traverses the emery deposit on North Mountain. The crystals are quite large, somewhat rounded, and deeply striated cubes. It is also disseminated rather commonly in the amphibolite that encloses the emery deposit on South Mountain.

A number of isolated crystals were obtained after removal of calcite from a veinlet in chlorite schist in which were present also magnetite octahedrons, epidote, titanite in rounded crystals, scales of chlorite, and feldspar anhedra. These crystals show dominant cube with subordinate faces of e (210), p (111), and n (211). The crystals are deeply pitted and contain magnetite octahedrons embedded in their mass.

Pyrite is very rare in the immediate vicinity of the emery. In but a single specimen of one of the corundophyllite veins containing crystallized magnetite, corundum, diaspore, etc., we found tiny pyrite crystals of cubical habit with narrow faces of e (210).

Chalcopyrite. The occurrence of this mineral in crystals has been mentioned above in describing cobaltite. These crystals were attacked by the acid used to remove calcite from the veins and were not measurable. They appeared to the eye to be steep, much striated sphenoids. The mineral is very sparingly present in the emery deposit.

Epidote. Epidote is abundant in the wall rocks of the emery bed and is found in many of the secondary veins. The best crystals obtained by us came from a calcite-filled vein in chlorite schist, together with chlorite and specular ilmenite. The slender epidote needles are pale yellow and quite transparent; the one crystal measured showed the forms c (001), a (100), u (210), m (110), k (012), o (011), n (111), and ρ (113); most of the needles, however, show no terminal planes and are deeply striated parallel to their length.

Tourmaline. Hexagonal prisms of black tourmaline without distinct

[8] Loc. cit., Monograph, 29, 116.

termination, closely resembling hornblende, are abundant in chlorite schist at Chester, the only common form of this mineral there. Two exceptional occurrences were noted in our collections. One specimen shows a sharp vein about 4 cm. thick, consisting of margarite plates set on edge on both walls, the central suture completely filled by radiating needles of black tourmaline. In a second specimen black prisms of tourmaline, intimately intermixed with epidote needles and plates of ilmenite, occupy a calcite-filled vein in amphibolite. The tourmaline is crystallized against the calcite and shows singly terminated crystals with the forms a ($11\bar{2}0$), m ($10\bar{1}0$), r ($10\bar{1}1$), and o ($02\bar{2}1$) in typical development. In both of these cases the tourmaline belongs to a later genetic stage than any recorded for the mineral by Emerson.

Albite. Veins of snow-white feldspar are frequently found in the amphibolite about Chester. In cavities the crystals are sometimes quite large and well formed. This feldspar was determined by its extinction angles as almost pure albite. The crystals are albite twins, tabular parallel to x ($\bar{1}01$), of pronounced pericline habit; the forms noted (by inspection only) were c (001), b (010), f (130), m (110), M ($1\bar{1}0$), and x ($\bar{1}01$).

Chlorite. Although beautifully sharp pseudo-hexagonal crystals of corundophyllite and amesite, respectively the dark and light green forms of chlorite common at Chester, are abundantly present in our collections, attempts to study them goniometrically were quite unsuccessful. The basal plane is alone of good quality; the pyramid planes are too deeply striated to yield any measurements. The appearance of these crystals is well described by Emerson,[9] and we can add nothing to his statements of the facts.

Other Minerals. A number of other minerals are represented in our collections from the Chester emery mine, but not in crystals permitting of even approximate measurement. A list of them is appended, to which are added four species, recorded by Emerson from the mine, which we did not see: margarite, chloritoid, hornblende, talc, oligoclase, titanite, calcite, aragonite, dolomite, malachite, azurite, hematite, pyrrhotite, and molybdenite, making in all some twenty-six species known from this locality.

In the large area of serpentine north of Chester Village, which, while it is not in physical connection with any part of the emery bed, is believed to have a genetic relation to it, are found the minerals chromite, magnetite, brucite, siderite, olivine, and picrosmine; brucite and olivine are new to the region and have been described elsewhere.[10] Other

[9] Loc. cit., Lexicon, pp. 16, 61; Monograph, p. 143.
[10] Am. Journ. Sci., **24**, 491 (1907).

mineral species recorded in lists of Chester minerals are either found in the schists which have a widespread occurrence in the town or in the granites and quartz veins which intersect them; they hence have no genetic relationship with those minerals contained in the emery bed and the associated amphibolite formation as a whole.

HARVARD UNIVERSITY,
March, 1909.